Evaluation of the global hydrologic cycle with HDO from TES

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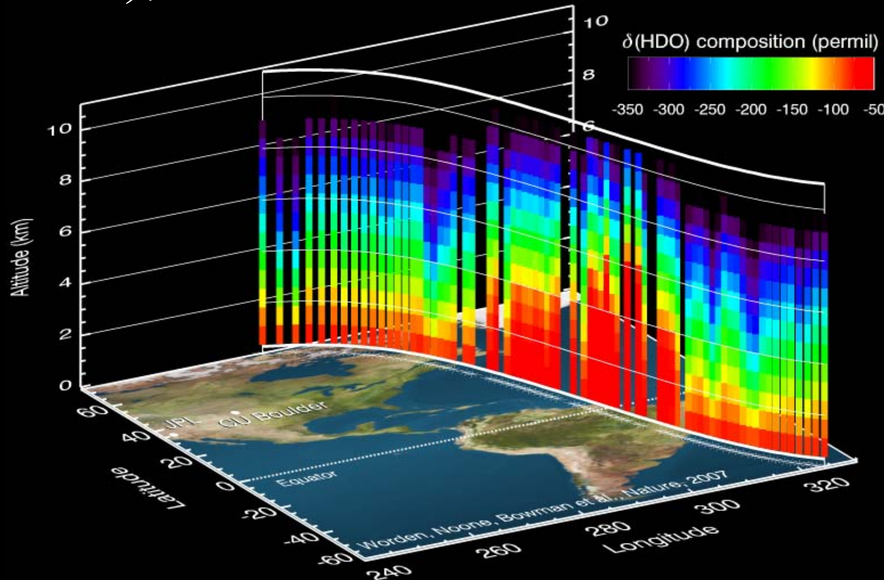
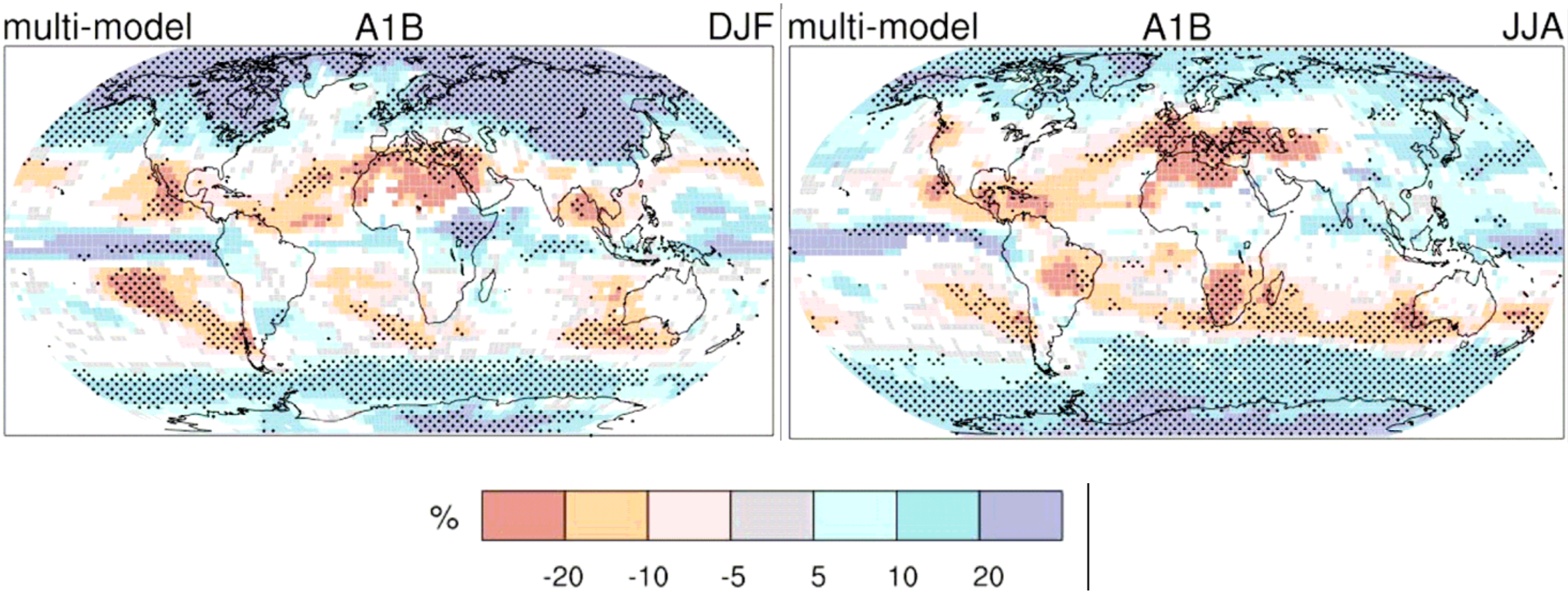


IPCC projected precipitation

Percentage change 2080-2090 relative to 1980-1999.



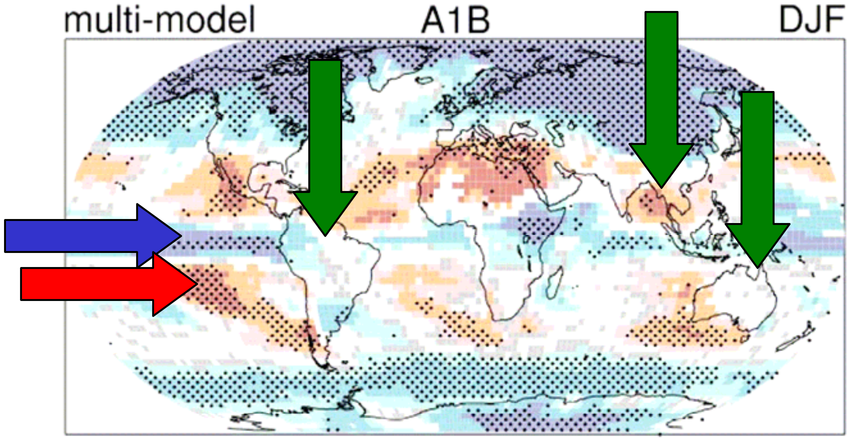
Patterns of changes linked to overturning circulation.

But which set of hydrologic processes have changed?

IPCC, Fourth Assessment, Summary for Policy Makers, Feb 2007.

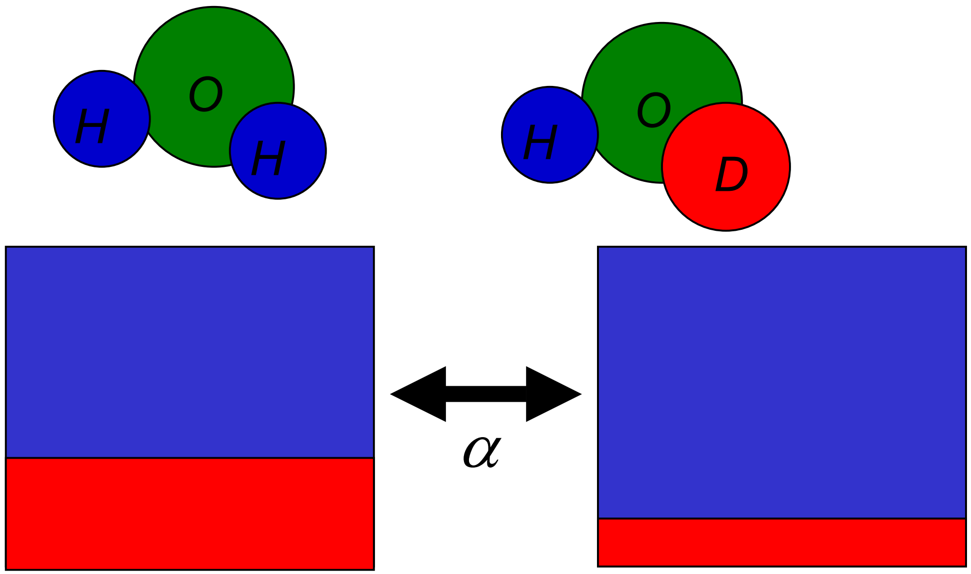
Overview

- Isotope physics (a reminder)
- Isotopes identity exchange processes (not just state)
  e.g., evaporation and condensation
- Continental hydrology and recycling
- Controls on global humidity
- Water exchange and hurricanes (not shown)
- Interannual variability in hydrology (not shown)



- Isotopes identify processes
- Isotopes give a measure "strength" of the hydrologic cycle
- Provides a unique compliment to water and temperature measurements
- Helps get the right explanation for the right reason

Reminder of isotope physics



liquid
(e.g., ocean)

vapor
(e.g., atmosphere)

Ratio of HDO to H_2O

Measured as a difference from ocean water.

$$\delta = \frac{R}{R_{ocn}} - 1$$

Two simple isotope models…

Condensation

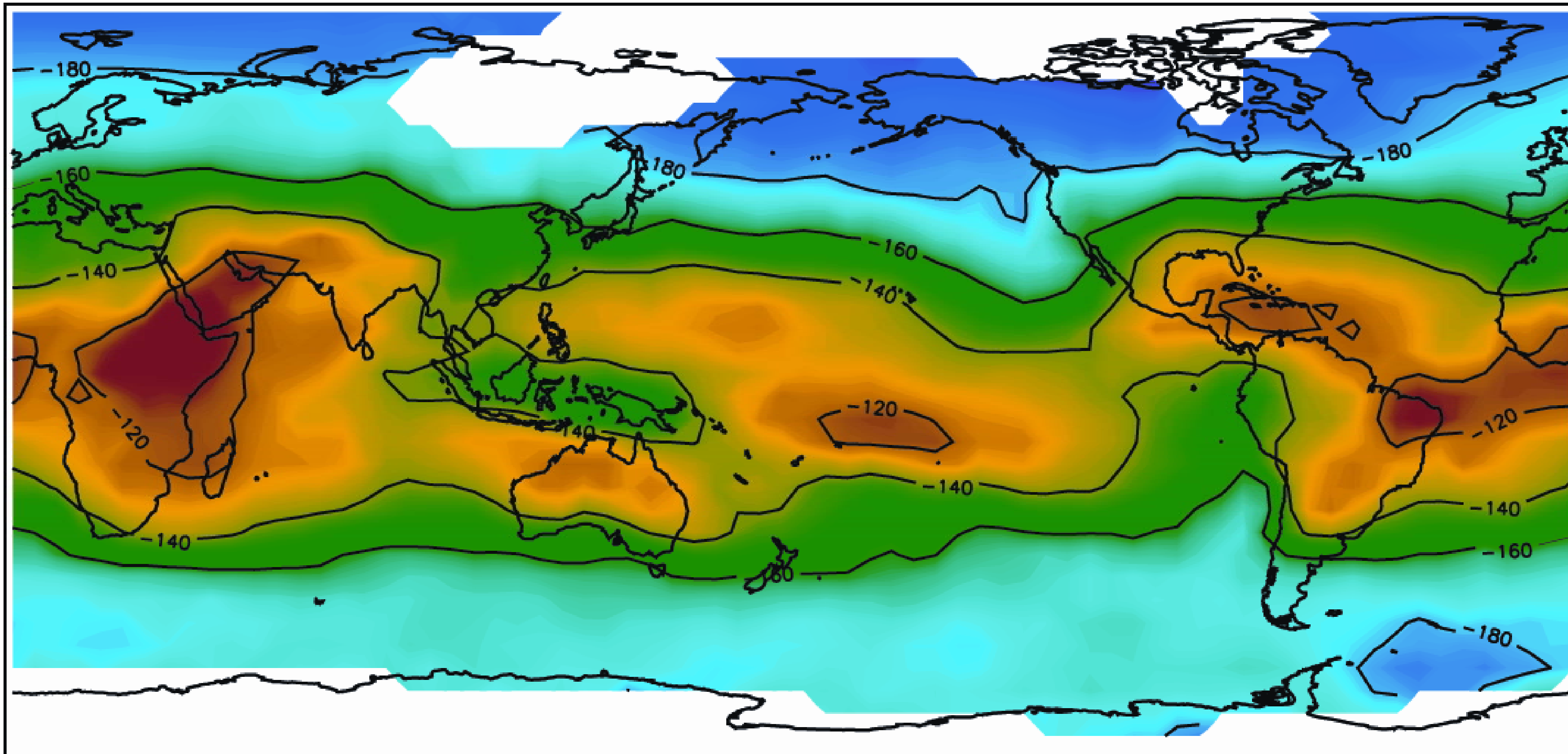
Vapor becomes depleted as heavy removed preferentially

Evaporation

Returns to isotopic composition of the (ocean/land) source.

Conditions under which condensation occurs is different from the conditions when evaporation occurs

Annual mean δD from TES

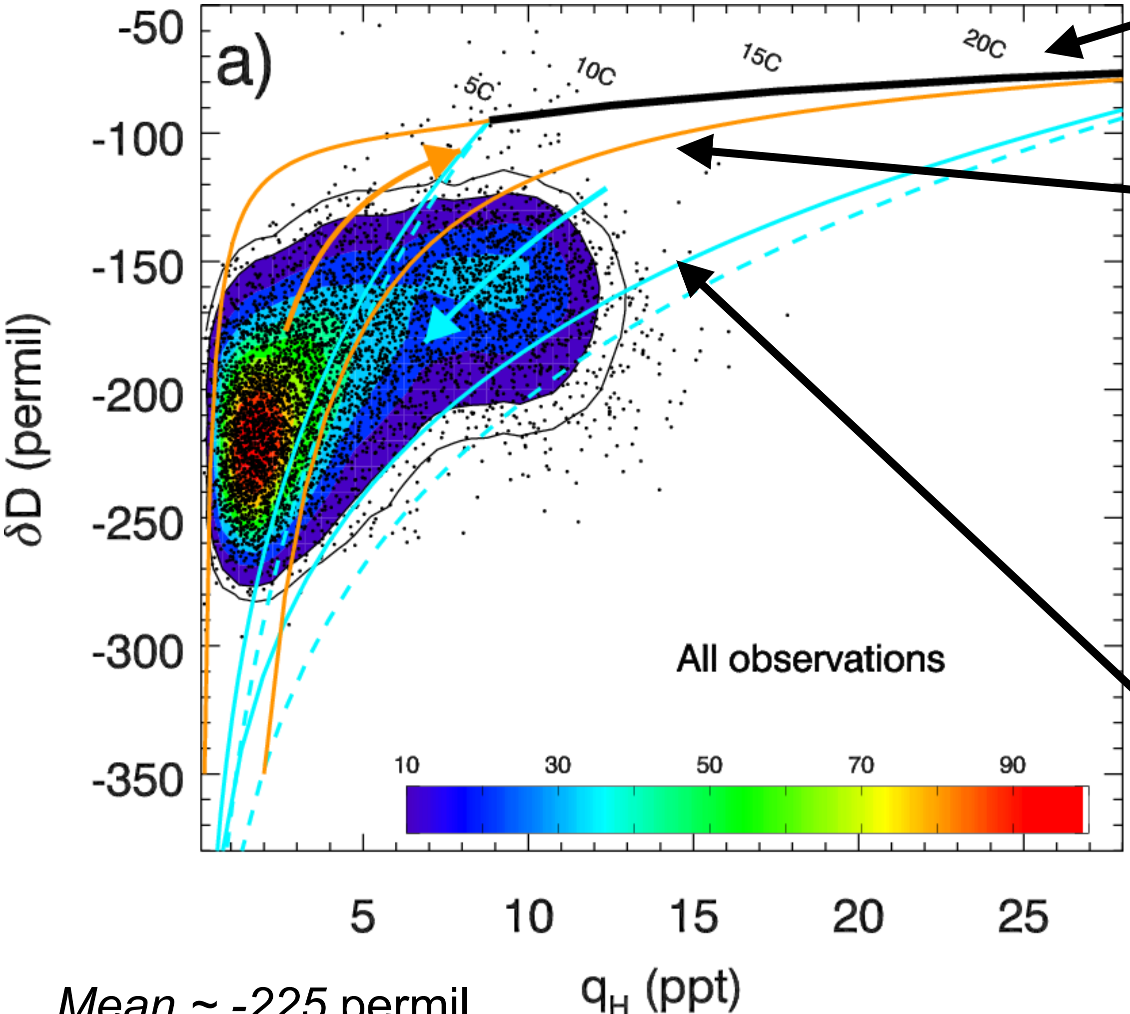


Layer average 825 to 500 hPa (max. sensitivity)

Data most reliable between 30N and 30S.

Noone *et al.*, GEWEX, 2007

The water *cycle*



Vapour in equilibrium with ocean water

Evaporation (*"mixing"*)

$$\frac{dq}{dt} = E = C(q_s - q)$$

$$\frac{dq_i}{dt} = E_i = C\eta(R_s q_s - Rq)$$

Rayleigh condensation

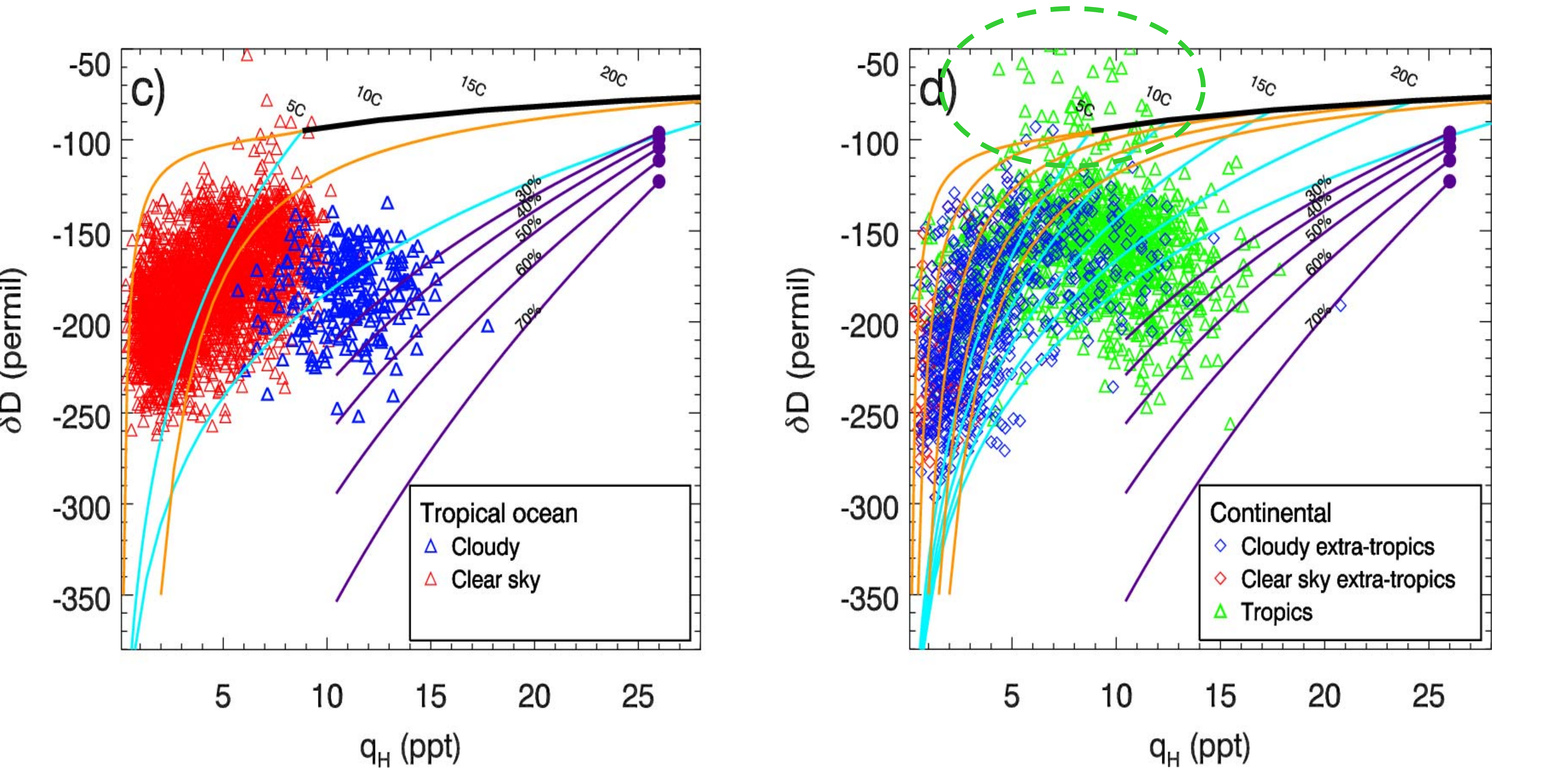
$$\frac{dq}{dt} = P$$

$$\frac{dq_i}{dt} = P_i = \alpha \frac{q_i}{q} P$$

Mean ~ -225 permil

Controlled by balance of condensation and boundary layer supply of oceanic water

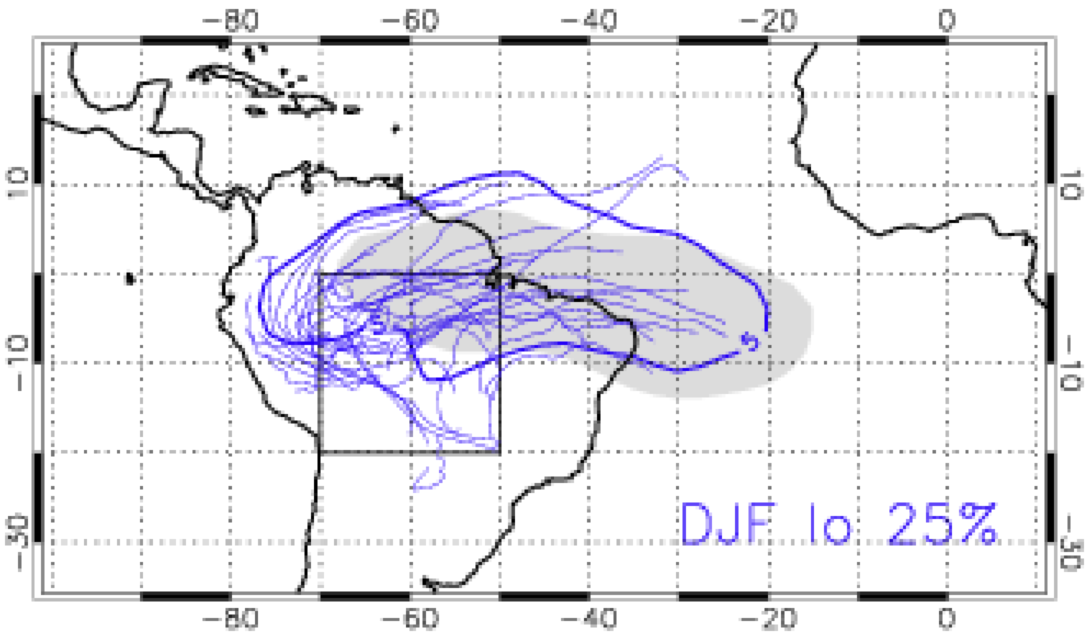
Fractionation efficiency $\alpha \sim 1.1$



Requires rain to be evaporated to explain distribution of cloudy points, since this gives and “extra” fractionation

Mass balance shows 20-50 % of rain evaporation needed

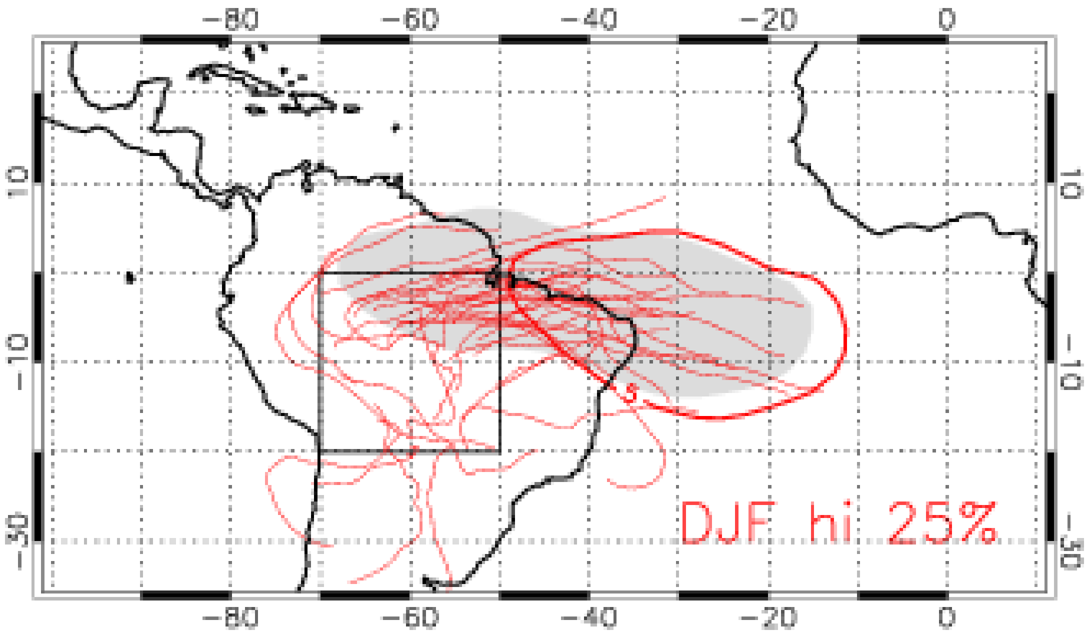
Enriched values can not be from ocean – signal of evaoptranspiration



Amazon wet season

Origin of air mass for most and lease depleted 25% of observations

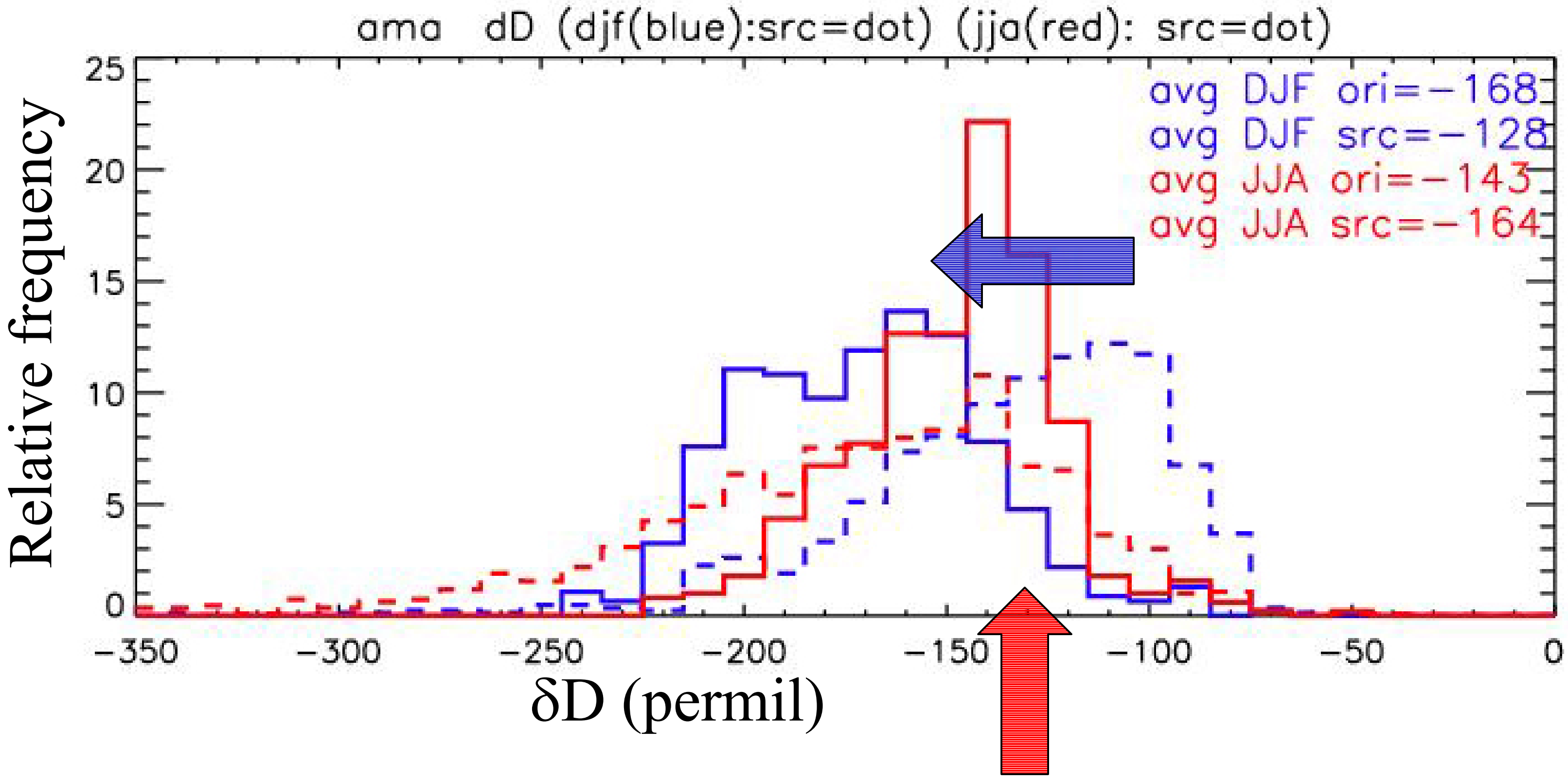
5-day back trajectories from all TES observations



Most depleted spend more time over land (local convection and condensation)

Least depleted more recently from the ocean.

Processes modify distribution (e.g. Amazon)



Dashed δD of 5-day origin
(mostly tropical Atlantic)

Addition of δD of source
(close to δD precipitation)

Solid δD over Amazon

Local recycling or other

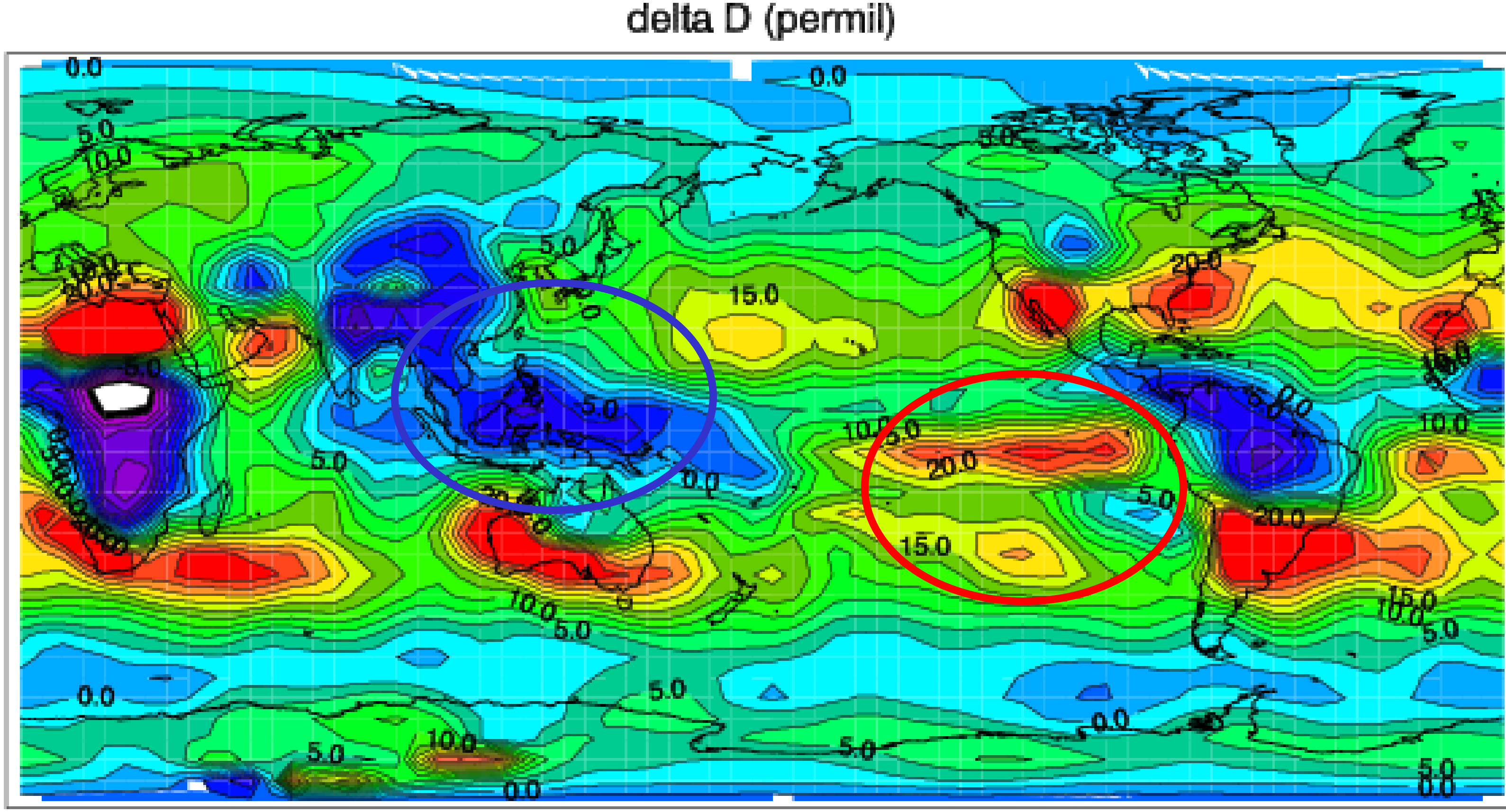
	Dry season				Wet season		
	E/C	f			E/C	f	
Amazon	97%	0	Continental recycling		0 ~33%	> 6% 30%	Advection source, strong conden.
N. Australia	86%	0	Continental recycling		0 ~20%	>3% 30%	Advection source, strong conden.
SE Asia	84%	0	Continental recycling		69%	0	Continental recycling

Based on TES δD difference observation minus origin
E/C is ratio of source relative to sink over 5 days
f is the fraction of rainfall evaporation

δD offers ONE constraint (either E/C or f)

What controls relative humidity?

Annual mean: δD when RH is high minus δD when RH is low



Humidity affects cloudiness (albedo, IR emission)

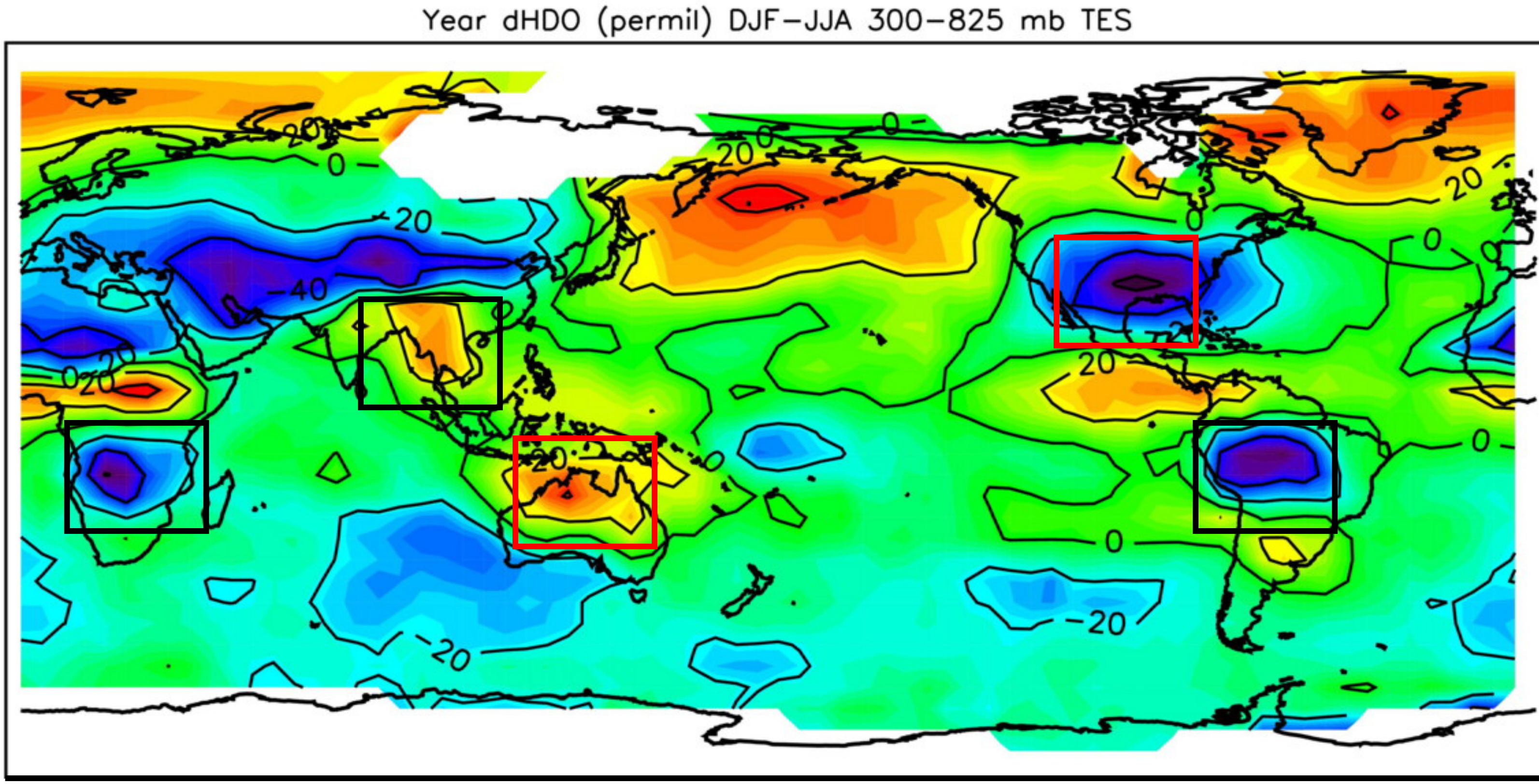
Mostly controlled by mixing with high latitude air in subtropics
(Controlled by cloud processes in convective zones)

Conclusions

1. Isotopes "***tag" water source water***, which indicates processes
2. Budget calculations of HDO and H_2O can give P ***and*** E (rather than P-E)
3. Hydrologic budgets as balance of ***fluxes*** directly from observations of isotope ***state***.
4. Isotope balance capture ***strength of water recycling*** (balance of advection versus local source)

- Gained confidence in TES data, characterization of uncertainty and how to use it effectively
- Branching to new problems
- Developing better estimation methods (including assimilation and more robust estimation approaches)

Seasonal difference



Wet season depletion - “amount effect”, evaporation of falling rain (conditions dominated by condensation processes)

Wet season enrichment? Different balance of fluxes.

Hypothesis: Lofting of vapor and detrainment (i.e., source dominates sink)